



# Automobile Exhaust Pollution and Purification Methods

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<p>Abstract</p> <p>As we all know, the automobile gas exhaust pollution has become more and more severe at recent years. It influences both to the human beings health and to quality of environment. The purpose of this thesis is to find out what are the main components of the exhaust gases, and give a basic and effective way to solve the problem.</p> <p>In this thesis, first the danger of exhaust pollution and its components will be presented. Then the writer will give the general mechanism of automobile exhaust emission. And many methods to control the pollution and make the purification better, like saving fuels, finding new energy to replace the traditional fossil fuels and so on.</p> <p>Through the exhaust emission controlling methods which are introduced in this thesis and the emission standards made by government, the quality of environment has been improved or protected obviously. In the future, continuous research on new energy and new technology can decrease the car exhaust gas pollution.</p>			
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## SYMOLS AND ABBREVIATIONS

CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
EV	electric vehicle
EPA	environmental protection agency
ECU	engine control unit
EGR	exhaust gas recirculated
HC	hydrocarbon
H <sub>2</sub> O	water
H <sub>2</sub>	hydrogen
N <sub>2</sub>	nitrogen
NO	nitric oxide
NO <sub>2</sub>	nitric dioxide
NGV	natural gas vehicle
PCV	positive crankcase ventilation
PM	particulate matter

# 1 INTRODUCTION

With the increasing number of vehicle, car exhaust pollution has become more and more rigorous. The exhaust gases will influence the environment and people's daily life. Like last winter, there was a famous car exhaust pollution event in capital city of China. The event is named as haze weather. In that period of time, the weather of Beijing was awful and the visibility was shortened to 10 meters. It not only damages people's health, but also influences the traffic and leads to a huge economic loss. People need to wear mask to go outside, because the haze will harm their sense of smell and breathe system. And due to the low visibility, some high-speed road was closed.

## 1.1 Background of study

Around 2.5 million cars burnt more than 1200 tons of petroleum each day in Los Angeles, 1943. The result of burning gasoline or petroleum causes hydrocarbon. The hydrocarbon will have a chemical reaction when it is irradiated by ultraviolet radiation of the sunlight. The exhaust gases will transfer into blue fog. A lot of people get sick because of this blue fog, some of them get red eyed, pain in head; some of them have problems in breathing system. From then on, people have called this kind of pollution smog. The smog event happened twice in Los Angeles, the first one was in 1955, and another one was in 1970. The smog made more than 400 people die because of breath crock up in 1955. And around 3/4 of the citizens got sick due to the smog in 1970. After these events, people started to realize the threat of car exhaust. Numerous environmental protectors are worrying about the danger of our earth and living environment. (Source: Automobile Exhaust Pollution, P1)

## 1.2 Purpose of the study and research

With the rapid development of economy, China's car possession has increased dramatically. City cars exhaust emissions raise fast, causing the exhaust pollution are increasing. The city cars exhaust pollution not only affects people's quality of life and health but also harms the local sustainable development.

The natural environment offers resources to people to live and develop, but it suffers a heavy damage caused by human beings activities. The purpose of this thesis is appeal to the people all over the world to protect our one and only earth. However,

solving the problem of car exhaust pollution is under high pressure, we need to take steps immediately. We hope that each of us will realize the importance of protecting the environment. Everyone should make a great effort to control automobile exhaust pollution.

### 1.3 Limitation of the study

Main information sources are internet or e-books, so the ideas in this thesis are writer's personal opinions which are only utilized for this single research.

### 1.4 The structure of the thesis

The introduction includes background of the study, purpose of the study and research, limitation and structure of the thesis.

Chapter two introduces the damage of automobile exhaust pollution, both for human health and environment. Then information for the main composition of exhaust gases, including own characteristics and damage is given.

Chapter three describes the generative mechanism of automobile emissions; it concludes the generative mechanism of carbon monoxide, hydrocarbon and NO<sub>x</sub>.

Chapter four introduces several methods to solve and control pollution. The article is focuses on 4 main parts, first is reduction of fuel consumption, then the second one is developing the new energy and new energy car. What is more, the in-engine control methods will be the third one. And the last method is tail gas catalyzing and refining technique.

In the last chapter, author gives the conclusion of automobile exhaust pollution and purification methods.

## 2 The danger of exhaust pollution and its composition

With the increasing number of personal and public cars, the exhaust pollution of vehicles has become more and more serious. The car exhaust gas has so many damages to environment and human health, and it becomes severe environmental problem in the world. Before dealing with this pollution problem, it is needed to find out the danger of exhaust pollution and its composition, and also the damages of each component.

### 2.1 The damage of exhaust pollution

The car exhaust gas is produced by the combustion of fossil fuels like natural gas, diesel fuel, and gasoline fuel and so on. The exhaust gases include so many toxic materials and discharged into atmosphere through the car tail gas pipe (see fig 1). (Exhaust gas, Available from: [http://en.wikipedia.org/wiki/Exhaust\\_gas](http://en.wikipedia.org/wiki/Exhaust_gas))



Figure 1. A diesel-powered truck emits an exhaust gas rich in black particulate matter when starting its engine. (A diesel powered truck. Available from: <http://en.wikipedia.org>)



The major hazard of automobile exhaust gas pollution can generally be divided into three parts. First of all, automobile exhaust gas will give a bad influence on human beings health. The exhaust gases mainly distribute from 0.3 to 2 meters' heights, so people can easily breathe the polluted air. It has a serious harm to the health of human body, can stimulate the respiratory tract and lower the immunity of the respiratory system. The strong carcinogen in tail gas like benzene class material will lead to lung cancer, thyroid cancer, etc.

What is more, the car emissions will destroy the ecosystem. A huge amount of car exhaust emissions can damage the ozone layer, so it will lead to the increase of solar radiation. It is the main reason for the greenhouse effect.

Last but not least, car tail gas can form acid rain. Because so many sulfur dioxide and nitride oxides emit to air, then transform to sulfuric acid and nitric acid. Soil acidification can be the result of acid rain. Meanwhile, acid rain also erodes the building, metal structure, and so on.

## 2.2 The composition of the emissions

The biggest part of most common combustion gas is nitrogen, carbon dioxide and water vapor: these compositions are noxious, even if the carbon dioxide will causes the greenhouse effect and leads to global warming. Only rarely part of exhaust gas is toxic materials, for instance carbon monoxide which caused by the incomplete combustion, hydrocarbons from unburnt fossil fuel, nitrogen oxide and particulate matter. (Exhaust gas. Available from: [http://en.wikipedia.org/wiki/Exhaust\\_gas](http://en.wikipedia.org/wiki/Exhaust_gas))

### 2.2.1 Carbon monoxide (CO)

Carbon monoxide is an interim atmospheric pollutant in some civic areas, mainly from the exhaust of internal combustion engines like cars, lawn movers, and power washer, but also from incomplete combustion of different kind of fuels including coal, gasoline, natural gas and wood. When the combustion engine works, if there is lack of oxygen or low temperature, the fuel can't perfect combustion, and then carbon monoxide will be produced. The carbon monoxide will mix with exhaust gas and discharge from the tailpipe. Another situation is that when the car is overload if you drive in a low speed or the engine idling, the fuel also can't combust completely. It will increase the ratio of carbon monoxide in the exhaust gas.

Carbon monoxide is a colorless, tasteless and odorless gas which is slighter than air, and it is extremely difficult for people to notice it. When people inhale carbon monoxide, it will quickly combine with hemoglobin to form carboxy-hemoglobin in the blood. (In Figure 2 is shown the structure of carboxy-hemoglobin.) They will prevent hemoglobin from releasing oxygen in tissues and deeply decrease the oxygen-carrying ability of blood. According to the research, the capability of carbon monoxide combined with hemoglobin is 210 times more than oxygen. For light carbon monoxide poison, the clinical symptoms include confusion, lightheadedness, and vertigo. Large exposures can lead to significant toxicity of central nervous system and heart, even death.

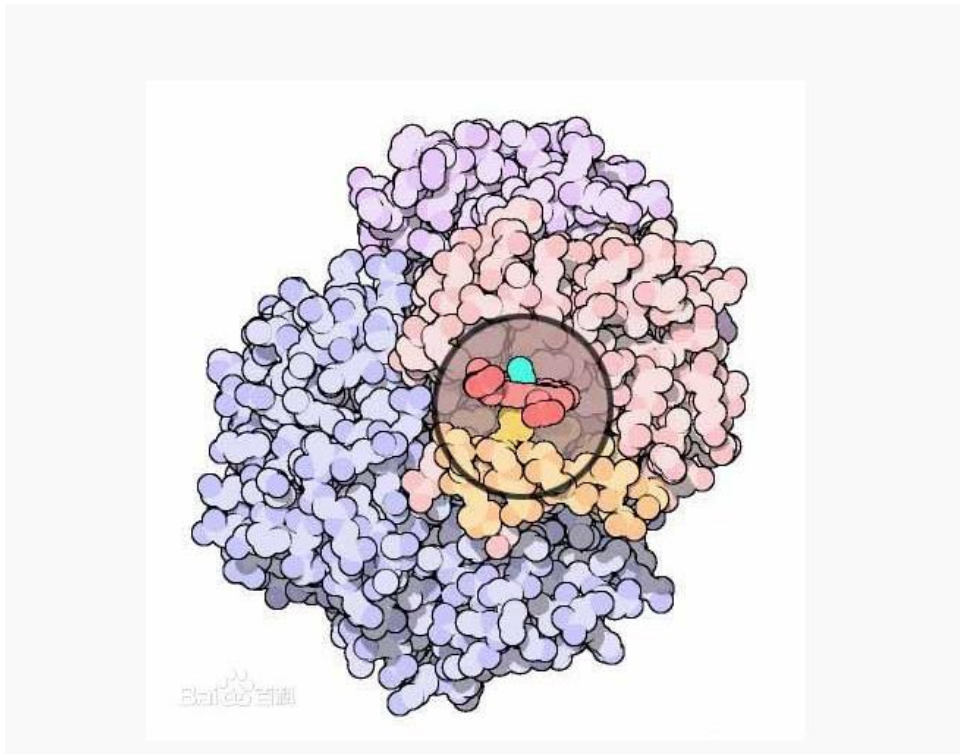


Figure 2. The picture shows the molecular structure of carboxy-hemoglobin (Carboxy-hemoglobin. Available from: <http://image.baidu.com/>)

### 2.2.2 Hydrocarbon (HC)

The produce of hydrocarbon is mainly due to fuel's incomplete combustion. Hydrocarbons are organic compounds which are consisting entirely of hydrogen and carbon. The direct harm of hydrocarbon leads to dizziness, nausea when the concentration of HC is high. When hydrocarbon reacts with nitrogen oxide, it forms irritant light blue photochemical smog under the solar ultra violet radiation. The main danger of

this blue photochemical smog is simulating eye and respiratory tract infection; cause the throat inflammable and pinkeye. When people are exposed in high concentration HC, it will increase the probability of skin cancer. For environmental and agricultural damage, the HC can destroy the ecosystem and impede the growth of crops. The direct outcome is reducing the agricultural productivity. Thus, Hydrocarbons have become another public hazard in automobile exhaust gas except carbon monoxide.

### 2.2.3 Nitride oxides (NO<sub>x</sub>)

NO<sub>x</sub> is the name of nitric oxide and nitrogen dioxide. They are produced during internal engine combustion, particularly at high pressure and temperature. Also when a motor engine working in a big and heavy load. The nitric oxide also can combine with the hemoglobin in the blood, and its combining capacity is bigger than carbon monoxide. So it is easy to let people poisoning and death. Nitrogen dioxide is a reddish-brown toxic gas. It will stimulate people's eyes, lungs and respiratory system. Nitride oxides are also parts of photochemical smog; it is the third public hazard in automobile exhaust gas.

For the environment effects, nitride oxides in the air will convert into nitric acid, which has been implicated in acid rain. Nevertheless, it is also a vital source of nutrition for plant life in the form of nitrates. What is more, both nitric oxide and nitrogen dioxide can deplete the ozone layer.

### 2.2.4 Particulate matter (PM)

Particulate matters are small pieces of solid or liquid matter combined with the Earth's atmosphere. Particulate matters are usually floating in the atmosphere, and it can see as the atmospheric impurities. As we all know, some particulate matters are produced by nature, like the volcanic eruption, dust storm and forest spontaneous combustion. In this thesis, we are focusing on the particulates produced by human activity. The main sources of PM are the fossil fuels combustion in automobiles, power plant and different kind of industrial process.

The damage of particulate matters is both on human health and vegetation. For human health, the effect of inhale particulates is quite serious. It will cause asthma, lung cancer, respiratory disease and premature death. According to the research, there have been 22,000 to 52,000 deaths per year due to the particulate pollution in the

United States from 2000, and lead to 370,000 premature deaths in Europe during 2005. (PM. Available from: <http://en.wikipedia.org/wiki/Particulates>)



Figure 3. The picture shows the PM pollution in Beijing. Air quality is bad due to the pollution and the visibility is considerable low. (PM. Available from: [http://en.wikipedia.org/wiki/File:Cloud\\_3.JPG](http://en.wikipedia.org/wiki/File:Cloud_3.JPG))

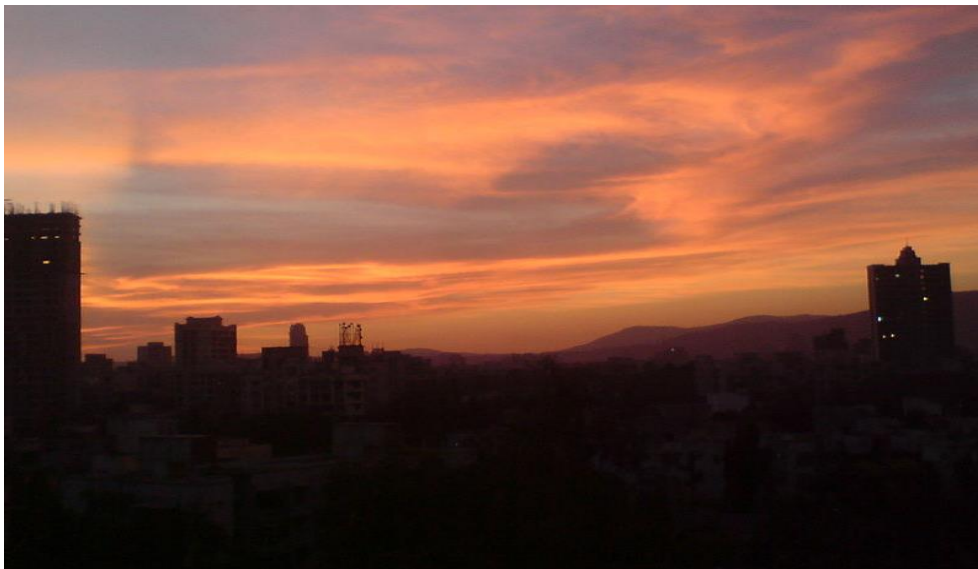


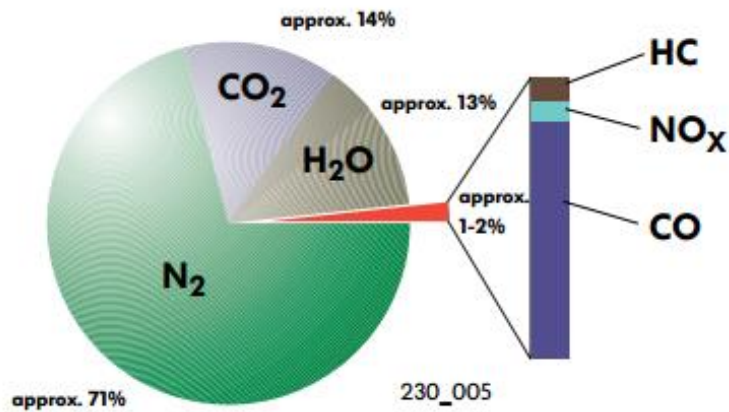
Figure 4. Particulates in the air cause shades of grey and pink in Mumbai during sunset. It really bring Mumbai so much air pollutant. (PM. Available from: [http://en.wikipedia.org/wiki/File:Cloud\\_3.JPG](http://en.wikipedia.org/wiki/File:Cloud_3.JPG))

### **3 The generative mechanism of automobile exhaust emissions**

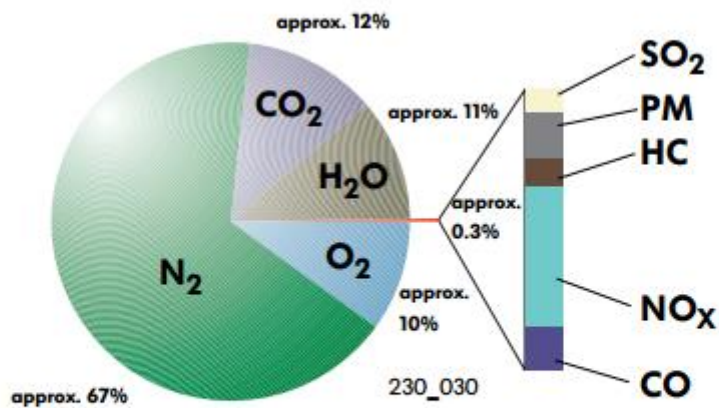
There are many factors influencing the automobile exhaust emissions, for instance the method of mixed gas formation, the combustion progress and the fuel. So the pollutant emission law of gasoline car and diesel car is different. Compare to the gasoline and diesel car; they have different type of fuel engine structure and use mixture gas formation and combustion in a different way, so the pollutant emission law is different.

There are some main differences between gasoline and diesel below.

- (1) Gasoline has strong volatility while diesel is hard to volatilize. Therefore gasoline vehicles have fuel emissions of pollutants, the composition is hydrocarbons
- (2) In gasoline car, there is very small amount of particulate matter. Because the fuel air mixture is forming outside the combustion chamber, before ignites the mixture gas needs to inlet and compression. It means there is enough time to make sure the fuel and air mixed uniformly. On the other hand, the petrol molecules are very small. All these reasons decide there is less particulate matter in gasoline car. While in diesel engine car, there is a large amount of PM. Because the mixture method and the combustion method is different. The formation of fuel and air mixture is occurring inside the combustion chamber and uses the heat of compression to initiate ignition and burn the fuel that has been injected into the combustion chamber. Thus, the fuel and air can't mix uniformly, and the molecules of diesel are big.
- (3) Gasoline engine car can produce more carbon monoxide than diesel engine car. The main reason is that the combustion method is different. Otto engine uses the spark-ignition design. It makes the combustion very quick. And the compress ratio of fuel and air is low. All this leads to the highest pressure is low and the highest temperature is high. It means that the combustion products will dissociate in a high temperature. So there is more carbon monoxide emission in gasoline engine car.



**Composition of exhaust emissions of petrol engines**



**Composition of exhaust emissions of diesel engines**

Figure 5. The former picture shows the main composition of exhaust emissions of petrol engines. The later picture shows the common composition of exhaust emissions of diesel engines. (Self-study Programme 230. Available from: [http://www.volkspage.net/technik/ssp/ssp/SSP\\_230.pdf](http://www.volkspage.net/technik/ssp/ssp/SSP_230.pdf))

### 3.1 Generative mechanism of carbon monoxide

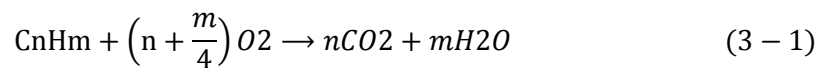
Carbon monoxide was one of the earliest pollutants which were found in automobile combustion products. It is also the most harmful composition in exhaust emission.

The produce of carbon monoxide is mainly due to the incomplete combustion of fuel.

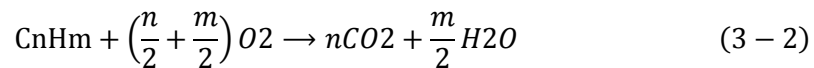
There are some reasons for the production of carbon monoxide below.

- (1) The incomplete combustion. When the hydrocarbon combust if there is not enough oxygen, it will cause the fuel incomplete combustion. So the fuel can't totally transfer into water and carbon dioxide, there is some carbon monoxide produced.

When air/fuel=14.7, hydrocarbon fuel can totally combust and product water and carbon dioxide.



When air/fuel<14.7, hydrocarbon fuel can't combust completely. Then it will produce carbon monoxide.



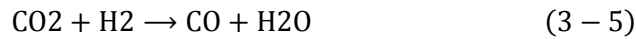
When air/fuel>14.7, oxygen is excess and there is no carbon monoxide produced. However, in real case, it is impossible that air and fuel mixture can mix uniformly to reach that value. So it always produced and emitted carbon monoxide.

- (2) Carbon dioxide will dissociate in high temperature. normally when temperature is more than 2000 °C, the carbon dioxide will dissociate and transfer to carbon monoxide.



The higher the temperature the more the carbon monoxide produced. Due to the temperature is higher the reaction will more violent.

- (3) Water will decompose to hydrogen and oxygen in high temperature. The hydrogen reacts with carbon dioxide and carbon dioxide will be reduced to carbon monoxide.



### 3.2 Generative mechanism of hydrocarbon (HC)

Hydrocarbons are unburnt fuel components which occur in the exhaust emissions after incomplete combustion. The mechanism of hydrocarbon is extremely complicated, it just introduces some main part of its generation.

- (1) Quench effect, it means the inter surface of combustion chamber quickly cool down the flame, makes the reaction slow down, and forms a thin layer of liquid air fuel mixture. When the car is running, the engine has already preheated, so there is no quench effect. The HC has been oxidized during the combustion reaction. The HC will emit from tail gas tube, it is the main reason for hydrocarbon generation. There are so many gap in combustion chamber, for example the gaps among piston, piston ring and cylinder, gap between spark plug electrodes. In this area, the quench effect is more remarkable. Flame is hard to reach these gaps. Air fuel mixture gas which in this gap may miss the main combustion step, when the combustion finished, the residual mixture gas will flow to the main room of the chamber due to the pressure decrease. And this mixture gases form the HC and eject to outside by tail gas pipe.
- (2) Oil film absorbs the air fuel mixture gas. On the surface of cylinder and piston, there is a thin oil lubrication film. When the fuel gas flows into the combustion room, the oil film will absorb small part of them, when the combustion is finished, the pressure in combustion chamber will be quickly decreased, and then the fuel gas in oil film will be released. But in this time, the temperature is low, so the released fuel gas can't completely combust. Then the residual fuel gas will form the HC.
- (3) In cold start and heat engine progress, the fuel gas can't combust totally because of the low temperature in combustion chamber. The incomplete combustion fuel gases also form the HC.



### 3.3 Generative mechanism of NO<sub>x</sub>

There are 3 main conditions influencing the formation of NO<sub>x</sub>. First is the high temperature. Normally when the temperature is higher than 2600 K, it starts to produce a large number of NO<sub>x</sub>. Second one is enough oxygen. Last one is time, the more time the air fuel gas stay in cylinder, the more NO<sub>x</sub> will be produced. Vice versa, the less time the air fuel gas stay in cylinder, the less NO<sub>x</sub> will be produced.

#### 3.3.1 Gasoline engine car

- (1) The concentration of oxygen has a vital influence on the formation of NO<sub>x</sub>. According to the research, when the concentration of oxygen reaches a certain value, the produce of NO<sub>x</sub> can get the maximum point. The concentration of NO<sub>x</sub> gets highest when the excess air ration equals to 1.1. It will hinder the producing of NO<sub>x</sub> due to the lack of air when excess air ratio is less than 1.1. If the value is more than 1.1, it also has a negative influence on producing of NO<sub>x</sub>, because of the more air and less fuel. It will lower down the temperature.



- (2) For gasoline engine, ignite timing also has a big influence on NO<sub>x</sub> producing. The delayed ignition systems can effectively decrease the NO<sub>x</sub>. Because if you use this system, it will reduce the highest temperature of combustion and shorten the time which gas stay in cylinder. As mentioned before, high temperature and time of gas stays in cylinder decide the output of NO<sub>x</sub>. Nevertheless, uses delayed ignition system will improve the fuel consumption.

#### 3.3.2 Diesel engine car

The diesel engine uses the compress heat to ignite the fuel gas. So the oil injection time has a tremendous effect on NO<sub>x</sub> producing. The delayed oil injection can decrease the NO<sub>x</sub> effectively. The system of diesel engine is quite similar with gasoline engine. The delayed oil injection also reduces the highest temperature of combustion and shortens the time of gas stay in cylinder.

## 4 Several methods to solve the pollution and purify the gas

As I mentioned in the former 3 chapters, automobile exhaust gas pollution has become the most serious problem in China, even in the world. It has a bad influence on environment, leads to the green-house effect. It also changes the climate, hinders the growth of crop. Meanwhile, exhaust gas has a huge negative influence on human beings health, sometimes exhaust gas will leads to death. So controlling the pollution and purifying the gas has become the most essential thing in the modern society.

Nowadays, the development of individual automotive technologies alone is not enough to reduce certain exhaust gas components and fuel consumption. Therefore, we need to look at vehicles as an integral whole and match all the automobile components to one another. Taking this integral approach to vehicle development as a basis, four main exhaust emission control strategies can be defined:

- Reduction of fuel consumption
- New energy
- In-engine control methods
- Out engine's purification

The following sections will explain these terms in detail. (Source: Automobile exhaust gas, P12)

### 4.1 Reduction of fuel consumption

Reduction of fuel consumption can be most effective and direct way to control the automobile exhaust gas pollution. Meanwhile, reductions of fuel consumption can aslo save energy. As we all known that fossil fuel is the non-renewable resource. Aerodynamic shape, saving the weight of car, tire types and good driving habit can deeply influence the fuel consumption.

Actually, there is a famous research project which aims at lowering the heavy vehicle fuel consumption. The time period is from 2003 to 2005, it takes 2 years. The main

sponsor is VTT, and there are 18 more sponsors in this project. By the way, Tekes and AKE are the biggest sponsors. In this research project, they give the energy saving potential in different technical methods, like:

1. Self-weight of car and aerodynamic (30%)
2. Auxiliary driving guide technology (5% - 15%)
3. Car types (5% - 15%)
4. Car tire types (5% - 15%)
5. Air in-let guide vane configuration (4% - 8%)
6. Lubricating oil (1% - 2%)

From the example list above, you can see the certain fuel saving potential percentage in each technical method. (Source: Automobile exhaust gas, P22)

#### 4.1.1 Aerodynamic applied in car shape designing

In 1923, Audi car and Company first used aerodynamic technology in car shape design. The principle of this aerodynamic body is based on Paul Jaray's theory who is the most famous aerodynamicist in Switzerland. The purpose of this aerodynamic body design in car industrials is to reduce the drag coefficient. If the drag coefficient is big, the drag force will be higher. That means you need more power to support your car driving normally, and according to the research the quicker the speed, the higher the drag force. Until the drag force reaches a certain value which decided by the weight of the car and speed of the car can get. Thus, lower drag means lower fuel consumption.

In aerodynamic subject, drag is named air resistance. It is a type of friction. Refers to forces acting opposite on the relative motion of any objective with respect to a surrounding air. Compared to other resistive forces, these dry frictions which are independent of velocity, drag force depends on velocity. (French, A. P. 1970, 35-40)

$$F_D = \frac{1}{2} \rho V^2 C_D A \quad (4 - 1)$$

Where

$F_D$  is the drag force,

$\rho$  is the density of the fluid,

$V$  is the speed of the object relative to the fluid,

$A$  is the cross sectional area, and

$C_D$  is the drag coefficient

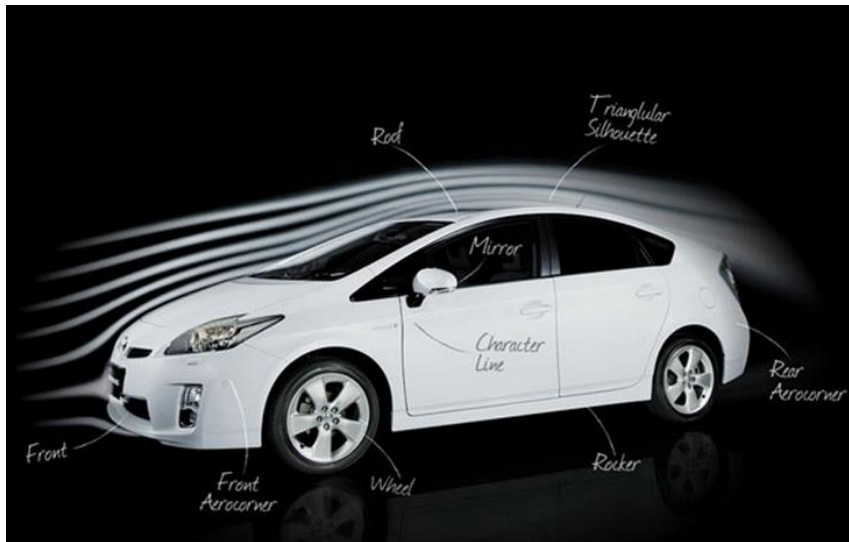


Figure 6. The picture shows the drag force acting on the vehicle.

(Self-study Programme 230. Available from:

[http://www.volkspage.net/technik/ssp/ssp/SSP\\_230.pdf](http://www.volkspage.net/technik/ssp/ssp/SSP_230.pdf))

#### 4.1.2 Saving car weight

Lightening car weight is an effective mean to realize the fuel conservation and emissions reduction. It is all known that weight of car has a big influence on energy consumption. According to the research, around 75% fuel consumption has a relationship with the total car weight. Decreasing the weight of car can efficiently lower the energy consumption and exhaust gas emission. At present time, many researches can prove that when a car loses 10% of their own weight, it will decrease 8% of oil consumption and 4% of exhaust gas emission.



Figure 7. This picture shows the frame structure of Audi Luop 3L TDI  
(Self-study Programme 230. Available from:  
[http://www.volkspage.net/technik/ssp/ssp/SSP\\_230.pdf](http://www.volkspage.net/technik/ssp/ssp/SSP_230.pdf))

Saving car weight is not just simple reduce the weight of car, you must meet the safety standards and the rising comfort levels of users. However, it is necessary because of the severe environmental pollution, it extremely urgent to save the energy and reduce the exhaust emission. Take the Audi A8 and Lupo 3L TDI as example, the space frame body construction of these vehicles is made of lightweight materials like aluminum and magnesium. Compared to steel, aluminum alloy is light, but the strength performance is better than the steel frame construction.

#### 4.1.3 Rolling resistance of tire

Car tire is one of the most important elements of the car, and fuel consumption has big relationship with tire. When the car is moving, the majority fuel consumption is used to conquer different kind of friction. Based on the professional testing, there are three main frictions acting on vehicle when the car is moving at 100 km/h uniformly. 60% of total friction is from air resistance, 15% from the friction of the car internal transmission system and 25% from the rolling resistance of tire. So from this data, you can see that how a tight relationship between tire and fuel consume.

Rolling resistance is also called rolling drag, it is the force resisting the motion when a body like ball, tire or wheel rolls on a surface. (Peck, William Guy, 29-30). The reason for the tire resistance is hysteresis. Because the characteristic of a deformation

material is that the deformation energy is more than recovery energy. The rubber compound in a tire has hysteresis. As the tire rotates quickly, it experiences repeated deformation and recovery circularly, and it leads to the hysteresis energy and mainly transfer into heat. So hysteresis is the main reason of energy loss associated with rolling resistance and is attributed to the viscoelastic characteristics of the rubber. (Samuel Kelly 1979, 60-61)

There are 4 main factors deciding the value of tire rolling resistance, tire section height and width ratio, hub diameter, tire material and air pressure inside tire. The resistance will decrease when the height and width ratio reduce. So we need to reduce the ratio in order to cut down the resistance. And when the hub diameter increases by 1 inch, the tire resistance will decrease 16%, but with the speed increasing, the trend will be slow down. Thus, adding diameter of car hub is another method to lower the friction. Meanwhile, using energy conservation tire also helps to debase the friction. Michelin Company developed an energy conservation tire Energy XM1 in 2005. This tire used special rubber which contained silicon element, can lower the resistance and add the road holding. According to the test by Michelin, this kind of tire can decrease fuel consumption by 5%. Air pressure of tire also influences the rolling friction, when the pressure is enough high, it will drop down the resistance. So checking the air pressure inside tire regularly can help to reduce the rolling friction and fuel consumption, it is a good way to control the exhaust emission.

#### 4.1.4 Auxiliary driving guide technology

The manipulation level of driver can also influence the fuel consumption. And compared to other methods to reduce the fuel consumption, this one can be the easiest way to solve the problem. Good driving habit can reduce the energy consumption, vice versa; bad driving habit will increase the fuel consumption.

For one same car, different driving style will lead to different fuel consumption. Several tips or good driving habit can save energy. First of all, when you stop your car for couple of minutes, please turn off your engine. Like when you drive car to buy some food in supermarket, you can turn off your engine, because it will use up one liter gasoline when the engine idled. What is more, driving slowly and steadily can help you save fuel, unnecessary acceleration or deceleration will produce extra fuel consumption. It needs driver familiar with the road condition, traffic condition and the performance of the car. Last but not least, you can close your window when driving. Be-

cause if you open the window, it will increase the drag force and add extra energy use.

## 4.2 New energy and new energy car

Using new and clean energy instead of traditional fossil fuel energy, can both help for sustainable development and reduce the automobile exhaust gas pollution. Nowadays, many countries have already started to develop new energy car, because the advantage of new energy car is enormous. All we know that, petrol and diesel is non-renewable resource, it will be used up in the future, so new energy car can solve this problem. Meanwhile, new energy car use new and clean energy as power source, it can tremendously reduce the vehicle emission pollution.

### 4.2.1 Electric car

The electric car is an automobile that is promoted by one or more electric motors, using electrical energy stored in a car batteries or any other device. And the benefits of electric cars compare to the traditional internal combustion engine automobiles include a significant reduction of air pollution, because they don't emit any pollutants from tailpipe. Electric engine will give cars instant torque and make the car accelerate smoothly. (Roth & Hans 201, 2–3.)

Although electric car doesn't produce emission gases, pollution is usually produced at power plants. Because the generated electricity will charges the vehicles' batteries. If 50% of the electricity is produced from coal, 30% from nuclear power, and 20% from natural gas, then the electric car will produce 99% less hydrocarbons, 99% less carbon oxide and 60% less NO<sub>x</sub>, compared with gasoline cars. (Johannson 1992, 3-4) So electric car can be applied to the specific markets where speed is no limitation like public transportation and urban use. Because it can reduce the local air pollution, create a good air condition in urban area.

In 1880, the first electric vehicle was produce and appeared in the world. Then they become popular in next few years. But electric vehicle didn't reach to mass product, because the development of internal combustion engine technology and cheaper gasoline or diesel vehicles are mass produced. Since 2008, more and more people have realized that the severe air pollution in the world and the increasing oil price, they put their interest on electric car again. (Sperling, Daniel & Gordon Deborah 2009, 22–26.)



Figure 8. The picture shows the electric car charging station in Paris, France.

(EV charging. Available from:

[http://www.iea.org/publications/globalevoutlook\\_2013.pdf](http://www.iea.org/publications/globalevoutlook_2013.pdf))

#### 4.2.2 Natural gas vehicle (NGV)

The natural gas vehicle also called NGV. This kind of car uses compressed natural gas or liquefied natural gas as a cleaner energy resource. (Worldwide NGV Statistics)

The advantages of natural gas vehicles over gasoline and diesel car are generally divided into 3 parts. First of all, natural gas burns more completely and produces less air pollutants than gasoline (see table 1). The NGV cars can dramatically decrease the emission of carbon oxide, carbon dioxide, sulfur dioxide and particulate matters. Meanwhile, there is no benzene and lead in the emission gas. What is more, natural gas tends to corrode and wear the parts of engine less rapidly than gasoline and diesel. Thus, the NGVs can save the maintenance cost compare to the normal fossil fuel



automobile. Last but not least, natural gas is renewable energy, and the price is cheaper than gasoline and diesel. (Natural gas vehicle, Available from: <http://en.wikipedia.org/wiki/NGV>)

Table 1. The reduction of emissions from NGV when compared to gasoline fueled vehicle. (In-engine purification. Available from: [http://www.iea.org/publications/globalevoutlook\\_2013.pdf](http://www.iea.org/publications/globalevoutlook_2013.pdf))

<b>Pollutants</b>	<b>% Reduction</b>
<b>CO</b>	<b>76</b>
<b>NOx</b>	<b>75</b>
<b>HCs (Non-methane)</b>	<b>88</b>
<b>Benzene</b>	<b>99</b>
<b>1,3-butadiene</b>	<b>100</b>

#### 4.2.3 Hybrid car

The hybrid car uses at least 2 distinct power sources to support the vehicle moving. Most common hybrid vehicle is hybrid electric-petroleum car, this kind of hybrid car using the internal combustion engine and electric motors as power source. The purpose of this kind of car is utilizing the energy and reducing the pollution maximized. Another popular hybrid car is hybrid petroleum-natural gas car. For this kind of cars, they use dual fuels as power sources.

Hybrid car can divide into 3 parts based on its connection system. First is series hybrid car, this kind of car is driven by the electric motor. The internal combustion engine drive the generator to produce electricity, the electricity will charge the empty battery. Then the battery will transfer electricity to drive the generator, the electricity will convert to kinetic energy, finally drive the car. This kind of system usually used in the urban bus, barely used in saloon car. Second is parallel hybrid car, the single electric motor and the internal combustion engine are fixed such that the vehicle either individually or together. This kind of design makes the vehicle and performs better in different kind of road condition. This last one is series-parallel hybrid car, there are two motors. (Electric motor and internal combustion engine) The power output in these motors can be shared to support the moving of vehicle via power splitter. The power splitter is a common planetary gear setup. This setup will control the power allocation. The proportion can from 0% to 100% for internal combustion engine, and

same for electric motor. And the combustion engine in this kind of system also can charge the battering like series hybrid car.

The hybrid vehicle basically reaches greater fuel economy and fewer emissions than traditional internal combustion engine vehicles. There are 3 main elements designs help hybrid car produce fewer emissions. (Garcia 2008, 21-22)

1. The hybrid car relies on the internal combustion engine and electric motors for the power needs. Due to this kind of design, the engine size will be smaller than normal automobile. And the smaller sized engine will generated less exhaust emission.
2. Electric and petroleum hybrid vehicle has a big capacity batter to store and reuse the recapture energy. For instance, the stop-and-go traffic of the city driving cycle.
3. The hybrid car can capture big amount of energy during braking progress which will be wasted as heat energy by normal car. The principle is that the regenerative braking setup will convert some kinetic energy into electricity to achieve the reducing of vehicle speed.

### 4.3 In-engine control methods

Automobile pollutants mainly come from following three parts, wasted gases exhausted from outlet, blow-by of crankcase and vaporization of fuel. For the blow-by of crankcase, the unique pressurized crankcase can recover all piston ring blow-by, further increasing compression efficiency and reducing the pollutants. Meanwhile, fuel vaporization control system can effectively solve the fuel vaporization. But the wasted gases exhausted from tailpipe are complex, thus it is the most difficult part to solving the automobile pollutants. Generally, it can divide into 2 parts, first is in-engine purification and control methods which will be presented in this chapter, another is application of tail gas filter which will be introduced in next chapter.

In-engine purification technology will change and improve the design of combustion engine, to deeply reduce the toxic pollutants in emission gas. In-engine purification technology is based on improving the gas inlet system, optimizing the combustion progress, using electronic control unit injector and exhaust gas recirculation (EGR).

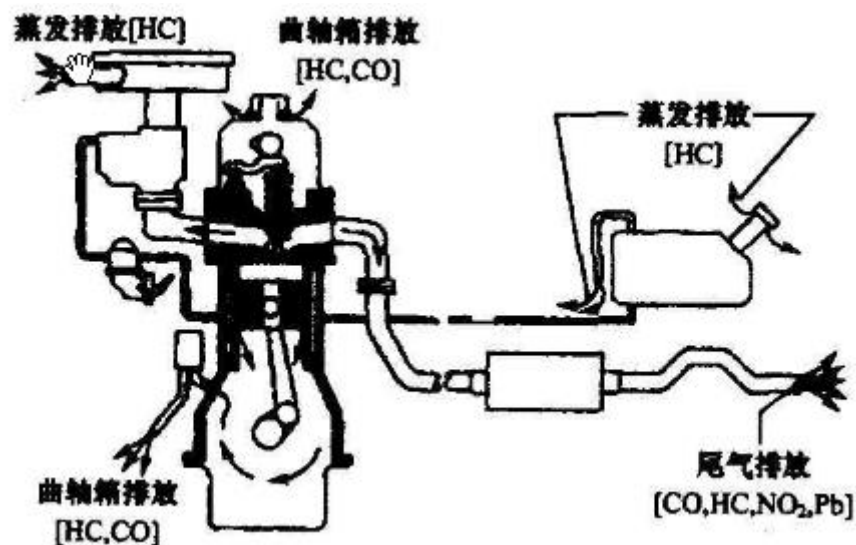


Figure 10. The picture is the sketch diagram of the main source of petroleum engine emission. (In-engine purification. Available from: <http://wenku.baidu.com>)

#### 4.3.1 Using engine control unit

The engine control unit (ECU) is a kind of electronic control unit which used in internal combustion engine. The initial purpose of this setup is controlling the actuators on internal combustion engine. This design will optimal the engine performance to reach

the target of improving the vehicle dynamic performance. But modern high technology ECU can also control the air/fuel mixture, ignition timing and idle speed, which deeply increasing the engine performance and effectively reduce the toxic pollutants in exhaust gas.

The ECU will control the air/fuel ration according to the number of parameters. When the throttle position sensor detect the throttle pedal is pressured down, then mass flow sensor will measure the amount of air which will be inlet into the engine, the ECU will inject a suitable quantity of fuel into the engine. It kind of design will make the fuel combust more completely in combustion progress, and reduce the pollutants in exhaust gas.

For gasoline engine, it needs a spark plug to initiate combustion in the combustion room. The ECU can select the best time to start the spark plug, and provide better power and reduce the fuel consumption. And it can prevent the knocking by delay the timing of the spark. Knocking is the result of the earlier ignition during the compression stroke.

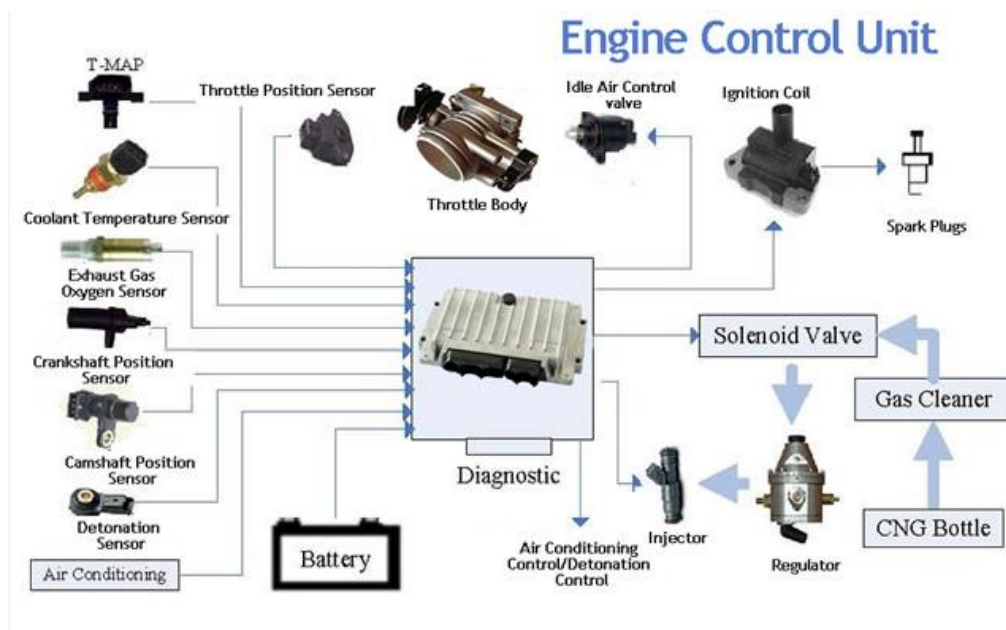


Figure 11. This picture shows the engine control unit. The ECU setup can control the spark plug to select the ignition time, control the throttle position sensor to calculate how much fuel need to be injected, and so on. (Engine control Unit. Available from: <http://upload.wikimedia.org>)

In general, the ECU device can help combustion engine performance better in both dynamic ability and reduce the pollutants like carbon monoxide, HC and NO<sub>x</sub> in exhaust gas. Using this device and technology can better the local air condition.

#### 4.3.2 Positive crankcase ventilation (PCV)

As I mentioned before, the blow-by of crankcase is a big part of automobile pollutants. And the positive crankcase ventilation can prevent the gases escape from crankcase of an internal combustion engine.

The PCV valve is a part of PCV system which the function is calibrating air leak with the help of PCV system, the engine returns the crankcase gases back to the air intake. Otherwise, the gases will be vented to the atmosphere leads to local air pollution. The principle of PCV system is that when the engine is working on light load, the air pressure of intake manifold is less than crankcase air pressure. The differences of air pressure, pulling the air in crankcase into intake manifold through the PCV valve.

The regular maintenance for PCV valve, air filter and spark plugs can help PCV system work well, and performance better in reducing blow-by gases in crankcase. It is very important that the PCV system must be kept clean. Otherwise air flow will be obstructed. And the plugged or malfunctioning PCV system will damage the engine. Normally, the PCV problems are due to the poor or neglected maintenance. So changes the air filter, and lubricates the engine can avoid this PCV problem. (Positive crankcase ventilation, [http://en.wikipedia.org/wiki/Crankcase\\_ventilation](http://en.wikipedia.org/wiki/Crankcase_ventilation))

#### 4.3.3 Exhaust gas recirculate (EGR)

Exhaust gas recirculated is a technology which can reduce the nitrogen oxide emissions in internal combustion engine. The system is that the EGR will recirculate a part of exhaust gas back to the cylinder. The returned gases from EGR system also have the equal concentration of NO<sub>x</sub> and CO. These returned gases will dilute the concentration of oxygen in combustion chamber, which reduce the combustion speed and temperature. Then it will reduce the NO<sub>x</sub> in exhaust emissions. Most modern engines need this exhaust gas recirculated system to meet the emission standard.

In spark-ignited engine, recirculated exhaust gases will increase the specific heat capacity of cylinder contents. It will lower the combustion temperature. In a typical gasoline engine, around 5-15% of exhaust gases will be routed back to the intake

progress. The maximum quantity is decided by the requirement of mixture to keep the continuous flame during the combustion progress. Over EGR will lead to the misfires and partial burns. So the correct use of EGR is important.

In diesel engine, the recirculated gases by EGR system will first be cooled with heat exchanger. After that, the gases will be intake to cylinder. Compare to spark-ignited engine, the maximum quantity of recirculated gas isn't limited by the need of continuous flame. Because the combustion progress in diesel engine is always excess air, it will make the EGR rates almost reach to 50%.

Basically, the engine recirculated gases are piped from the exhaust part to the air intake part. This equipment is named external EGR. An EGR valve within the circuit regulates the gas flow. Modern EGR system utilizing electronic engine control computers, multiple control inputs normally enhance the performance with no impact on motility. (Nagel 2002, 21-34)

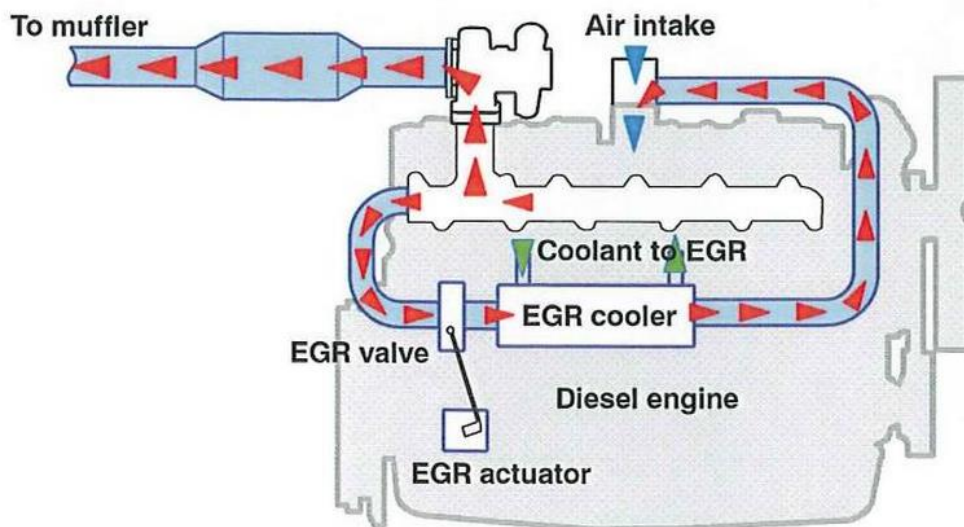


Figure 12. This is a structure diagram of EGR system, this picture shows the basic work principle of exhaust gas recirculated system. (EGR system. Available from: <http://en.wikipedia.org/wiki/File:SaabHengine.jpg>)

## 4.4 Tail gas catalyzing and refining technique

With the development of the air pollution of car exhaust gases, the laws and regulation have become stricter. Automobile exhaust gas catalyzing and refining technique is the most effective way to control the emission, and reduce the pollutants. There are many kinds of automobile purification catalysts. In the early time, the car industry usually used metal like copper, chromium and nickel as catalyst. It kinds of metal catalyst has low catalytic activity, and toxicity. Then use noble metal as catalyst, like platinum and palladium were used. The lifetime of this noble metal catalyst is long, and has good performance on catalyzing the exhaust gases. Unfortunately, this kind of metal is too expensive and hard to use widely. In this part, it will systematically analyze the improvement and different types of catalyzing and refining technology.

### 4.4.1 Development of catalyzing and refining technique

A catalytic converter is applied in internal combustion engine, like gasoline engine and diesel engine. It is car exhaust gas control equipment that can transfer toxic pollutants in emission gas to less toxic pollutants through reduction or oxidation.

Eugene Houdry, who's a French mechanical engineer and expert in catalytic oil refining, invented the catalytic converter in 1950. At that time, there was a biggest car exhaust gas pollution event in United States, which called Los Angeles photochemical pollution, Eugene started to concerned about the smoke and exhaust gas pollution. Then he invented the first catalytic converter for gasoline engine used on vehicles.

From the perspective of the stage of catalyst research, car industries used oxidation catalysts as major catalyst and the main active ingredient was platinum and palladium. This kind of catalyst was used for purification of auto carbon monoxide and hydrocarbon in exhaust gas. With the more and more strict emission regulation and limitation of nitrogen oxides, this kind of catalyst was gradually replaced by three-way catalyst. In the late 70s, people used Pt-Rh alloy and three-way catalyst in catalyzing technology. Most three-way catalyst uses precious metal as active component. Due to the catalyst market expands worldwide; the demand of precious metal is continuous increasing. But the price of the precious metal is expensive. So reduce the dosage of noble metals become the major research after 90s.

#### 4.4.2 Types of catalytic and purification system

There are 4 main types of catalytic and purification system. First is three-way catalytic system, it can reduce the hydrocarbon, carbon monoxide and nitrogen oxides at the same time. Second one is catalytic oxidation system; it can reduce the composition of hydrocarbon and carbon monoxide in exhaust emissions. Then the third one is catalytic reduction system, this system use copper oxide as catalyst. When the concentration of exhaust gas is high, the copper oxide will convert nitrogen oxide to nitrogen and ammonia. The last one is occlusion reduction purification system, mainly uses for purification the nitrogen oxides in thin engine. Because of the exhaust regulations around the world increasingly strict, Japan, the United States and Germany install three-way catalyzing and purification device in every cars to control the toxic pollutants effectively.

#### 4.4.3 Components of three-way catalytic converter

Three-way catalyst closed loop control system is one of the most common exhaust purification systems in the world now. This system can effectively control the main pollutants like carbon monoxide, hydrocarbon and nitrogen oxides in exhaust emissions at the same time. Three-way catalytic converter mainly consists of carrier, coating, active matter, and the shell. The carrier of this converter is cellular ceramic. And the active matter is metal platinum and palladium. Platinum usually catalyzes the oxidation of hydrocarbon and carbon monoxide. Palladium can catalyze the reduction of nitrogen oxides. The ratio of Pt and Rh is 5:1.

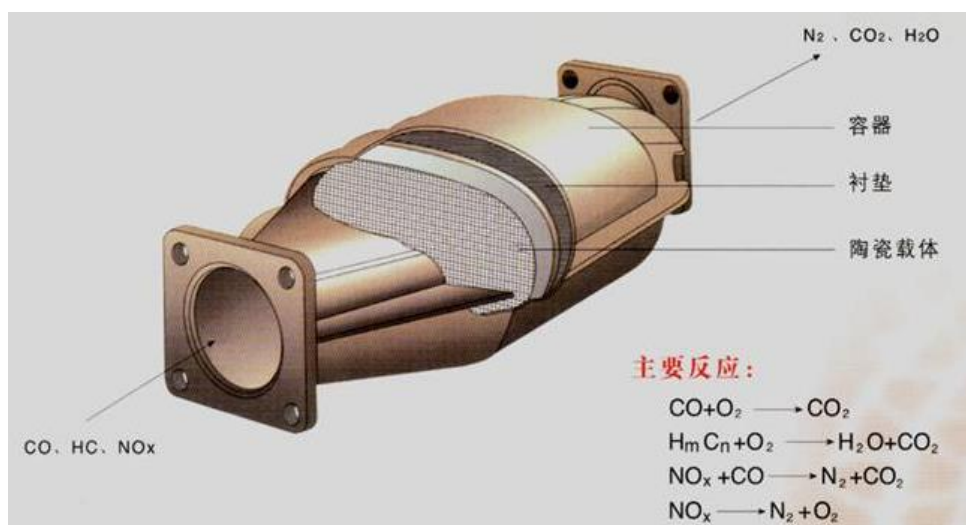


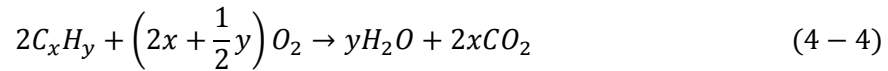
Figure 13. The section view of three-way catalytic converter shows the main component and the major reaction in this converter. (Three way catalyst. Available from <http://en.wikipedia.org>)



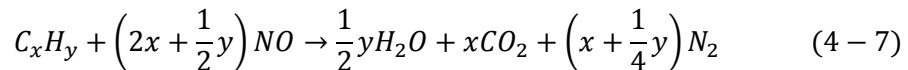
#### 4.4.4 Main reaction and analysis of working process

From the chemical reaction formula below, nitric oxide will be transferred to nitrogen by reduction reaction, and the carbon monoxide and hydrocarbon will be converted to carbon dioxide and water by oxidation reaction. When the concentration of oxygen in combustion chamber is low, the oxidation reaction can't react completely. Vice versa, when concentration of oxygen in combustion chamber is high, the reduction reaction can't react completely. Thus, three-way catalytic converter has a certain requirement of air-fuel ratio. Only the real air-fuel ratio approaching to the theory air-fuel ratio, the converter can purify the pollutants more efficiency. In order to improve the purify efficiency of three-way converter, it is necessary to install a closed loop fuel injection control system in engine. To promise the air-fuel ratio is almost equal to theory air-fuel ratio.

##### 1) Oxidation of CO and HC:



##### 2) Reduction of nitrogen oxides:



##### 3) Other reaction:



## 5 Result

As we all know, automobile exhaust gas pollution has become global environmental problem recently. Reducing and controlling the exhaust gas can be our duty to protect the earth and our living environment, because on the one hand the gas pollution will deeply damage the environment, leading to some natural hazards like greenhouse effect, haze, photochemical pollution and so on. On the other hand, the gas pollution will have a bad influence on people's health, like respiratory system problem, red eyed, lung cancer. In this thesis, many ways have been presented.

### 5.1 Control and purification methods

First of all, author put his attention on reducing the fuel consumption of vehicles. It is the most direct way to reduce and controls the exhaust gases. In this aspect, there are four suggestions. First, design shape of the car by using aerodynamic system, in order to lower down the resistance of wind. Second, reduce fuel consumption by saving the car weight. Then, lower tire and rolling resistance to make the target of saving fuel come true. At last, suggest the driver use a good driving habit to reduce unnecessary fuel and oil consume.

Then, writer focuses on the research and application of new energy car. Using new energy car is the most effective way to reduce the exhaust gases, because the new energy car breaks down the traditional fuel structure. For example, EV uses electricity as power source, there is no carbon dioxide or any other toxic gases released. In this aspect, writer recommends three main new energy cars. The first one is electric car. The EV uses electricity as power source, which is friendly to environment. But the drawback is smaller driving force compare to gasoline car. Second one is natural gas vehicle, NGV uses natural gas as power source, compare to normal car, the merit of NGV is that the power source is renewable and less toxic exhaust gases released. Last one is hybrid car, this kind of car have at least more than two power source, can increasing the car power in the urban area, and also reduce the exhaust gas released in city area.

What is more, in-engine control methods were researched in this thesis. First using engine control unit to make the engine perform better and utilize the fuel. Then using positive crankcase ventilation system, to reduce the exhaust gas goes outside of combustion chamber. At last exhaust gas recirculate system has been suggested to

setup in the car, this system can recycle part of exhaust car to reduce the exhaust gas emission.

Last but not least, tail gas catalyzing and refining technique. The three-way catalytic can be the most popular and common tail gas filter at present time. In this part, the history and development of tail gas catalyzing and refining technique are introduced. Then the components of the three-way catalytic and the working process are analyzed.

## 5.2 Environmental improvement

Vehicles can be a symbol of modern industrial civilization; it really makes us more convenient in our daily life. But it also brings us so many environmental problems at the same time, for instance greenhouse effect, Beijing haze event, and photochemical pollution in America. People and scholars start to pay their attention to solving the pollution problem.

In European country, they made a strict standard for exhaust emission. In 1996, European Union makes the EU I standard to limit the emission of vehicle. And from 2005 to present time, the EU IV standard has been used in controlling the car exhaust emission. Japan, America and some other developed countries also have their own regulations to restrict the emission. Due to this severe regulation, the car exhaust gas controlling plan has got a great result. There is a real examples can prove it, the amount of vehicle in Japan is 12 times more than the car in Shanghai, but the emission of car exhaust gases in Japan is same with the emission in Shanghai. It means that the strict standard has really helpful in controlling exhaust emission.

Table 3. The concentration of Nitrogen dioxide in recent 20 years  
(Statistics of air quality. Available from: <http://www.epa.gov>)

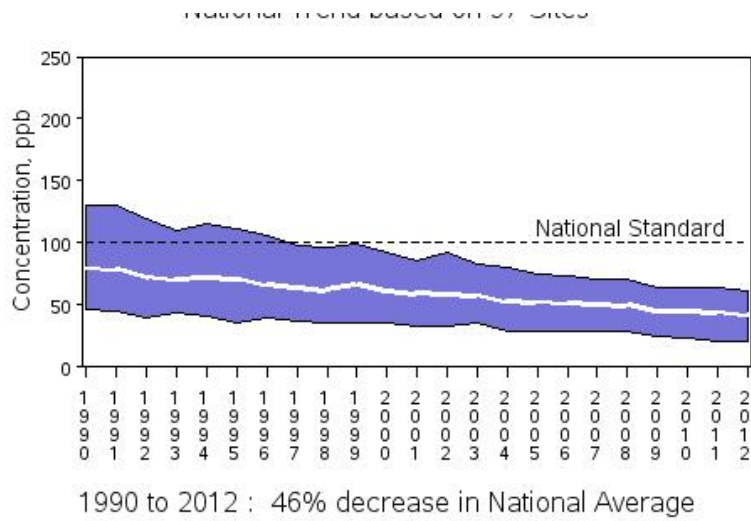
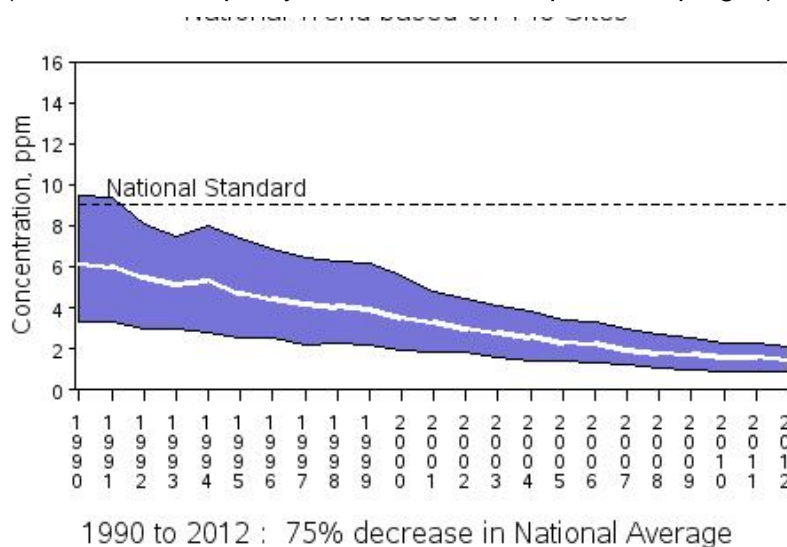


Table 4. The concentration of carbon monoxide in recent 20 years  
(Statistics of air quality. Available form: <http://www.epa.gov>)



Through the exhaust emission controlling methods which introduced in this thesis and the emission standards made by government, the quality of environment has been improved or protected obviously. For example, the content of nitrogen dioxide and carbon monoxide in exhaust gas has been respectively decreased 46% and 75% from 1990 in America (see table 3 and 4), due to the American government publish the strict emission standards and laws, and many advanced purification technology. Like EGR system, development of new energy and optimizing of internal combustion engine. These new technology and regulation make the controlling plan succeed, and let the quality of environment improved.

### 5.3 What can be done in the future

For developing countries, like China and India, they can learn the experience from European country. Made the strict regulation for car emission, learn the newest technology of controlling and purification the exhaust gases.

For a European country they can continually research the new and clear energy to replace the gasoline. Majority of the cars are still using the diesel and gasoline as power source in the world. Widely using of new energy car or new energy can be the major subject in controlling the exhaust gas in the future.

From table 4 below, the carbon dioxide emissions increased slightly from 1870 to 1950. Since 1950, the emissions has raised dramatically, due to the improvement of industrial and human activity. Largely used of automobile also contributed to the carbon dioxide emission. And from table 5, we can see that coal, oil and gas are the major energy resource of industrial and automobile, change the energy structure can be the most important and effective way to reduce the pollutant emission.

Table 4. CO<sub>2</sub> emissions from fossil fuel combustion in recent years  
(Statistics of car emission. Available from: <http://www.iea.org>)

GtCO<sub>2</sub>

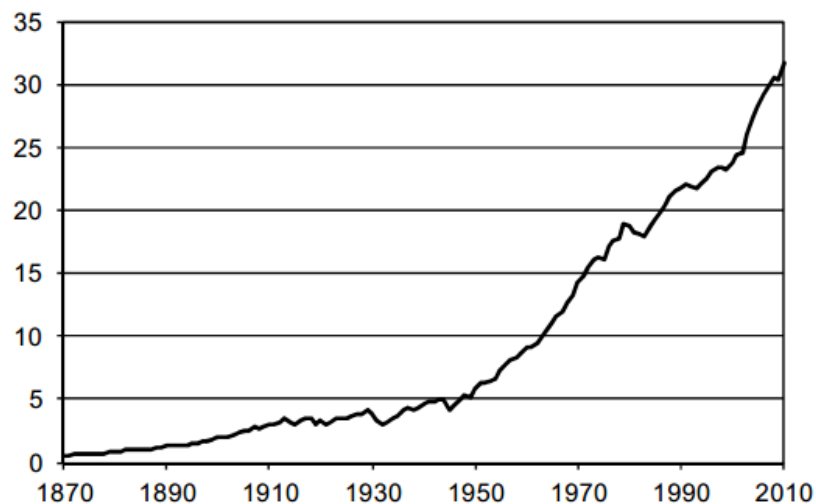
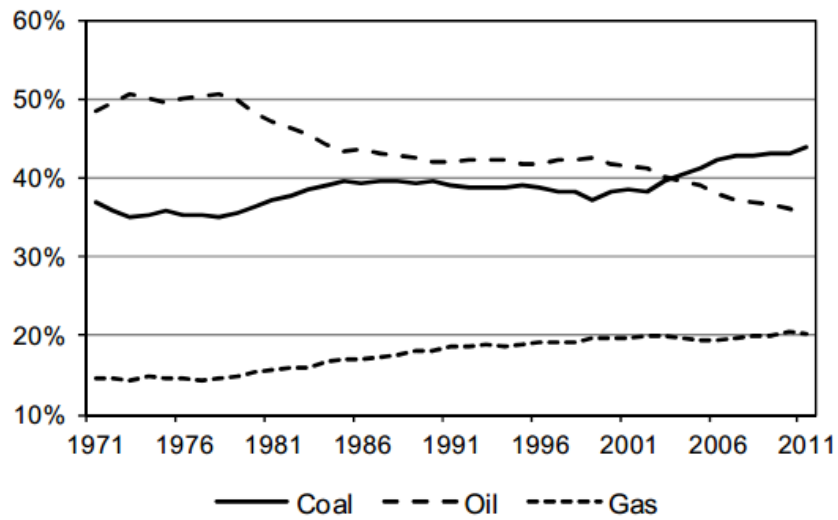


Table 5. Fuel shares in global CO<sub>2</sub> emissions (Statistics of car emission.  
Available from: <http://www.iea.org>)



## 6 Conclusion

Nowadays, vehicles play a vital role in our daily life. There is no doubt that automobiles can bring us a tremendous convenience, they impact and shape the world in so many ways. Meanwhile, the emission of automobiles also leads to the air pollution in the world, the pollution damage the world both in human health and natural environment.

In the recent, both the economic and industrial developed rapidly; people put more attention on economic rather than environmental protection or long-term development. Meanwhile, we also need to focus on the air pollution problem and human health. Quite many major challenges need to be solved now, for instance diversifying the energy structure, because the fossil fuel is non-renewable and will emit toxic pollutants after combustion. Then controlling pollutant emissions and cutting greenhouse gas emissions also are the most vital things now. The automobile exhaust pollution makes severe damage to people's life and health.

In this thesis, first the background information and some pollution examples were presented in the introduction part. Then in chapter two and three, it describes the harm or damage of the exhaust gas, the generative mechanism and composition of the exhaust gases in detail.

Chapter four introduces several methods to control and purify the exhaust gas pollution. The most effective way is reduce the fuel consumption, through reducing the weight of the car and using aerodynamic design in car. Then changes the fuel construction also is an available method to reduce the air pollution, using new energy and new energy car to replace the fossil fuel and conventional automobile. What is more, utilizing and optimizing the internal combustion engine also can be the useful way to control and diminish the emission. Last, application of three-way catalyst converter and technique in the automobile also can be as a practical means to purify the exhaust and toxic pollutants.

Control emission of car couldn't be solved in short time. With the development of purification technology and new energy technology, the air pollution caused by numerous automobiles will be maximally controlled and reduced in the future.

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**Picture**

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